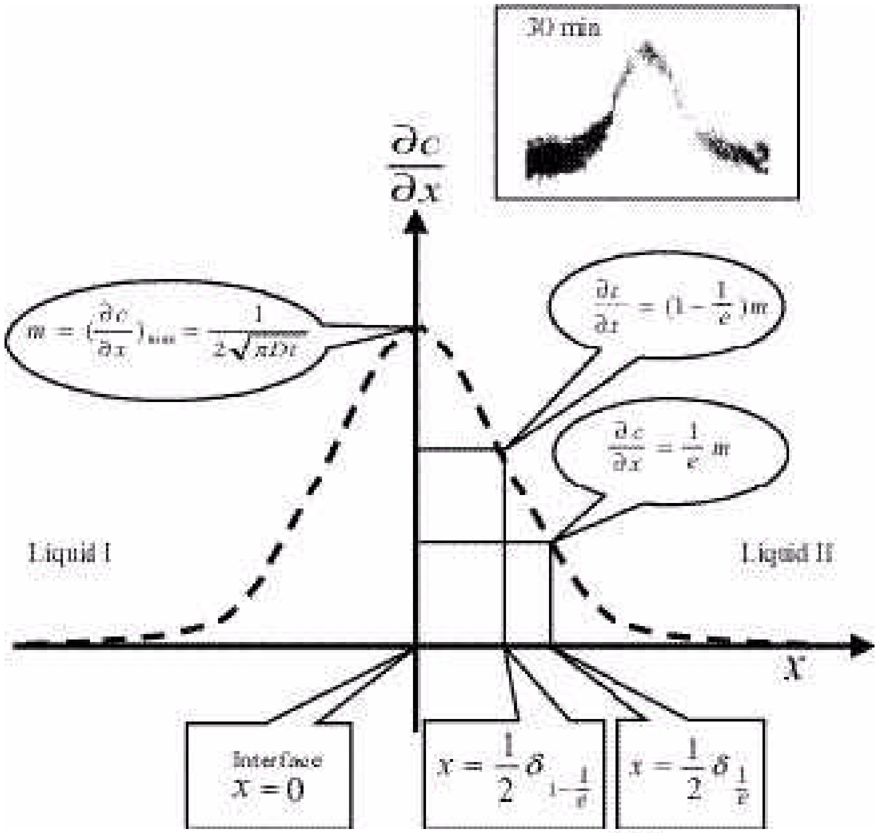
Diffusivity Measurements Made Instant and Easy

A compact common path interferometer (CPI) system has been developed to measure the diffusivity of liquid pairs. The CPI is an optical technique that can be used to measure changes in the gradient of the refraction index of transparent materials. It uses a shearing interferometer that shares the same optical path from a laser light source to the final imaging plane. The molecular diffusion coefficient of liquids can be determined from the physical relations between changes in the optical path length and liquid phase properties. When the data obtained by using the CPI have been compared with similar results from other techniques, the instrument has been demonstrated to be far superior to other instruments for measuring the diffusivity of miscible liquids while staying very compact and robust (ref. 1). Because of its compactness and ease of use, the CPI has been adopted for use in studies of interface dynamics as well as other diffusion-controlled process applications (ref. 2). This progress will permit experiments in microgravity that can quantitatively answer basic science questions about mass and thermal diffusion and their effect in transport processes. This instrument is a spinoff of a diagnostic development for microgravity fluid physics experiments at the NASA Glenn Research Center that has used optics and electronics existing in the fluid physics laboratory for feasibility studies.

Optical diagnostic techniques have become an integral part of many areas of measurement applications in industrial and research laboratories. Many types of interferometers and their phase-shifted versions have been used as instruments for measuring optical wave fronts for lens testing and combustion and fluid flow diagnostics. One of these, the point diffraction interferometer, is considered to be robust (see, for example, ref. 3) because it has a common-path design. The point diffraction interferometer is difficult to align and has a limited measurement range for liquid-phase applications. Interferometry and schlieren techniques have been widely used for many years for gas-flow-visualization. On the other hand, the CPI, which is basically a Wollaston prism Polarizer in combination with an analyser (crystalline quartz retardation plate) is used instead of a point diffraction interferometer unit. The advantage of using the CPI over other optical techniques is that it can make quantitative measurements in liquids with the large index of refraction variations that often occur in interface dynamics studies. This can be simply accomplished by using different prism polarizers for each particular experimental condition.



A typical traced fringe (concentration gradient profile $\partial c/\partial x$) near the interface after fluids came in contact (inset shows the actual fringe after 30 min). Typical straightforward data points for diffusivity D calculations are also shown on the traced shifted fringe. (Note: All dimensions are normalized by the maximum m value.)

Miscible fluid flows are important in enhanced oil recovery, fixed bed regeneration, hydrology, and filtration. The dynamics of miscible interfaces is an active area of research that has been identified to benefit from experimentation in reduced gravity. The diffusivity is an important thermophysical property in such experiments. Its measurement is required to determine the ranges for experimental parameters such as the displacement speed, so that the effects of convection and diffusion are in optimal balance.

Recently, a new approach was developed that uses the CPI to measure the diffusivity of a pair of miscible fluids at any instant after they come in contact. The mathematical model underlying this new approach has been defined (ref. 4). The results are in excellent agreement with existing available data and are far more reliable because of a real-time measurement approach. Results of the first set of measurements have been published by Rashidnia et al. (ref. 1). The physical property data measured by the CPI will greatly help in defining the test results and the mathematical modeling of an experiment planned (ref. 2) to be conducted on the International Space Station in 2005.

References

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